Virtual environment for teaching Radiotherapy Physics – a four year experience

The Revd Dr Mike Kirby

Lecturer – Radiotherapy Physics;

Chaplain – Liverpool Cathedral

Radiotherapy Directorate, School of Health Sciences,

University of Liverpool, United Kingdom

University of Liverpool 16th L&T Conference, Liverpool, UK; 5th July 2018

UNIVERSITY OF LIVERPOOL

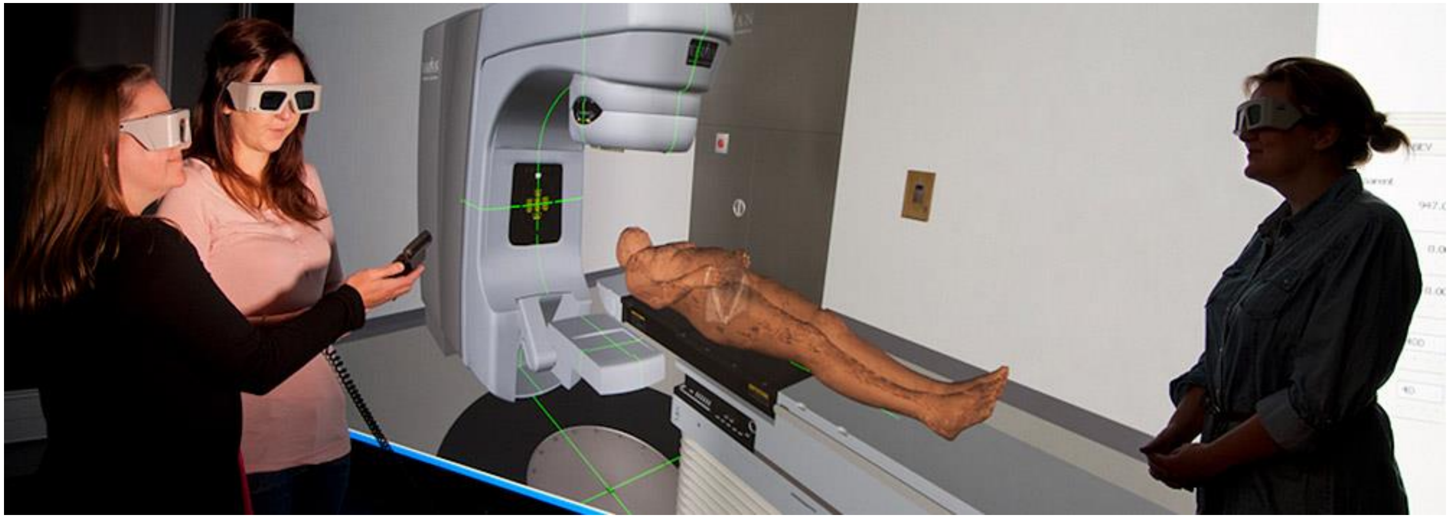
Introduction

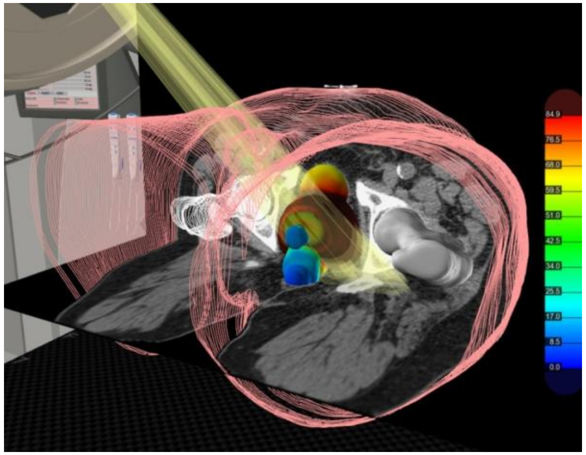
- It is often a challenge for therapeutic radiography students….to balance;
  - Proficiency in the scientific/physics aspects of radiotherapy <u>and</u>
  - well developed clinical and patient care skills

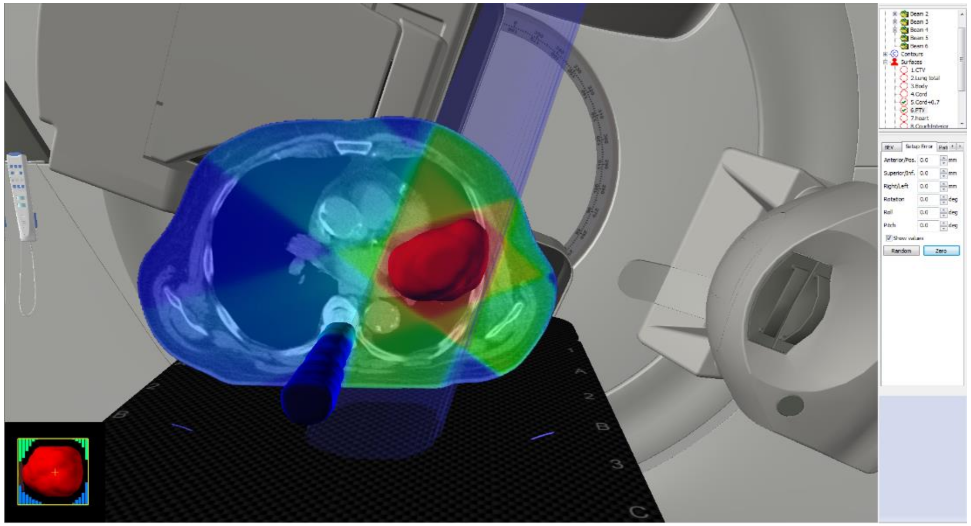
- In order to encourage every student to develop this balance and attain their best potential……
  - We need blended learning and teaching approach
    - Using a range of learning and teaching techniques
    - Using tools to help learn aspects of radiotherapy Physics which they don't encounter routinely first-hand on clinical placement during training

- Does a virtual environment (through VERT Physics) have a role to play here? Our four year experience (five separate iterations worth) says…
  - **YES!**

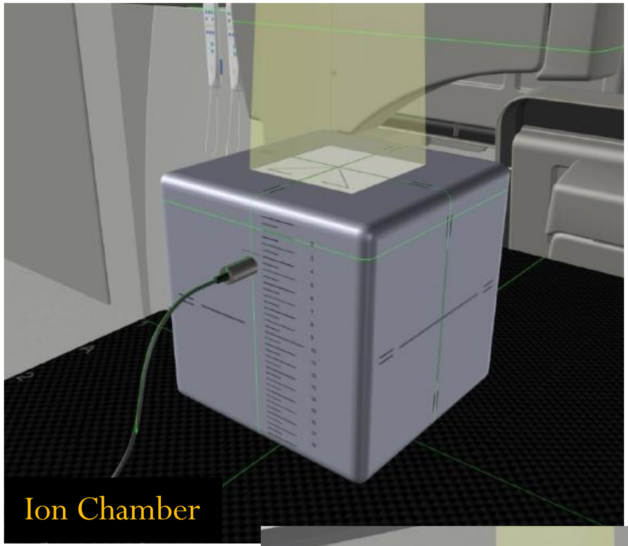
VERT™ (Virtual Environment for Radiotherapy Training)

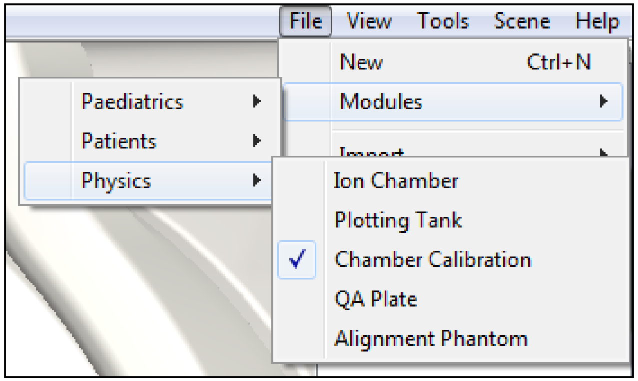


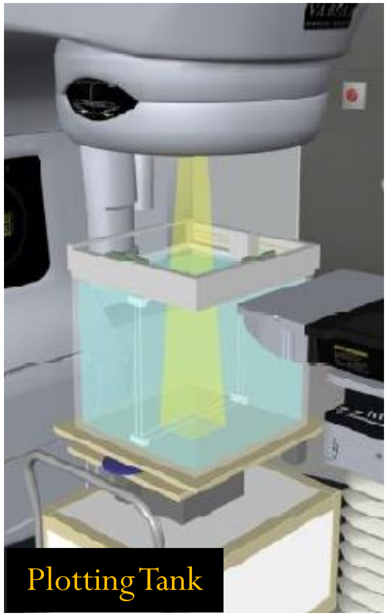


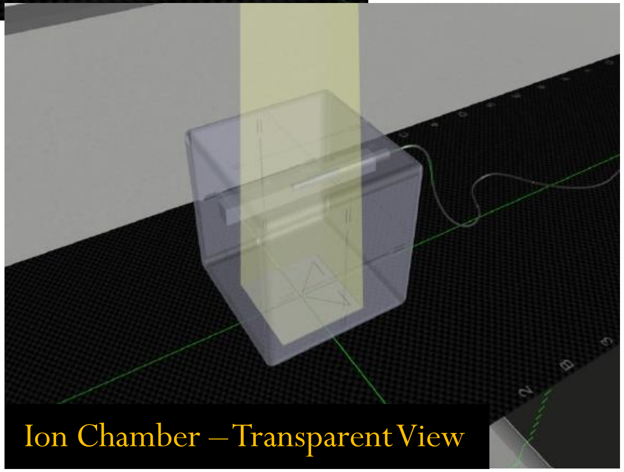


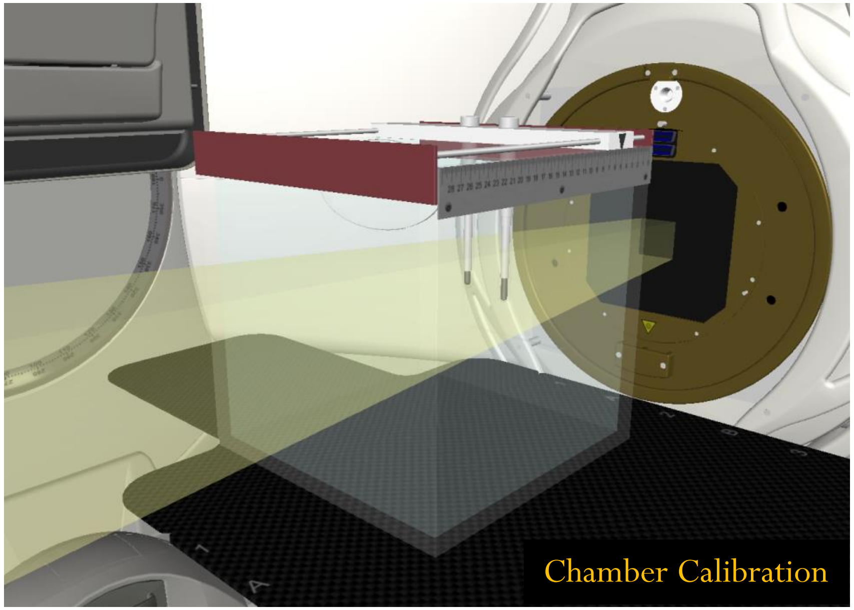
VERT^{TM} Physics overview











UNIVERSITY OF LIVERPOOL

Materials and Methods

- Year group divided into small groups – approx. 6 – 9 in each
  - 2nd years – Undergraduate (BSc) program; 1st and 2nd years – Postgraduate (PGDip) program
  - 2014, 2015 and 2016

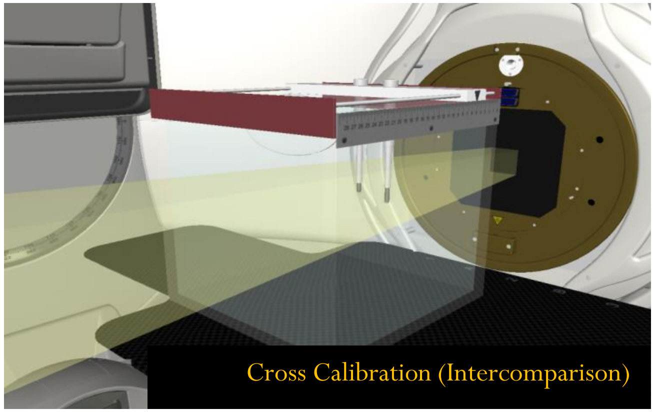
- 2 hours slot
  - Formal lecture (2014 only)
    - Revise/Introduce Science concepts
    - Dropped for subsequent years
      - To give more time to practical work
  - VERT Physics overview
  - Simulation for Practical experiments
    - VERT Physics is used as the teaching tool
    - Simulating the style of experiments/teaching done on an actual, clinical treatment machine (which we call a Linac)

UNIVERSITY OF LIVERPOOL

Lecture and VERT Physics Overview

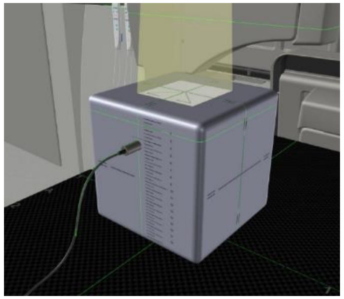
- Lecture
  - Recap on concepts covered in the semester…..
  - Inverse Square Law
    - The simple dosimetric effect of SSD changes
  - Percentage Depth Dose Curves
    - How they are measured and their use in beam energy specifiers (one of the fundamental parts of radiation dosimetry and dosemeter calibration)
  - Field Size Factors
    - Their meaning
    - How we get the numbers used

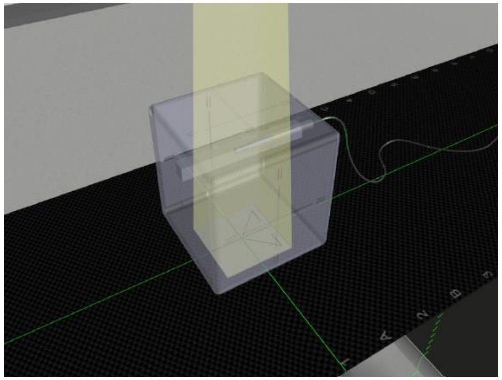
- VERT Physics
  - Ion Chamber module
  - Plotting Tank
  - Cross Calibration (Intercomparison) for Dosemeters

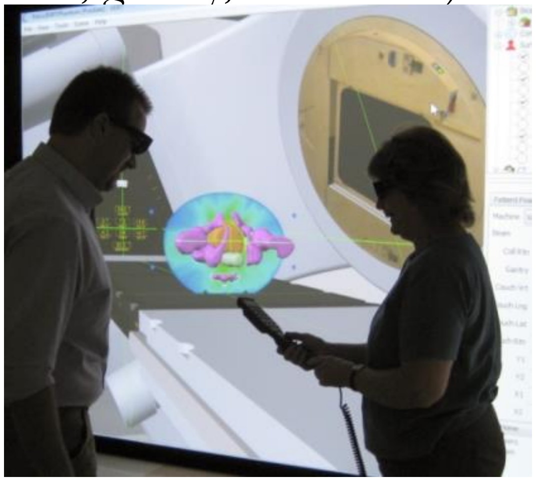


VERT Physics overview ctd.

- Advantages
  - Instant ion chamber changes – no holes in the phantom!
  - See through the phantom!
  - Concepts of isocentricity, 100cm FSD, prescription point etc.
- Disadvantages
  - No variation in virtual measurements
  - Instant set-up using field selection; so…..
    - Groups asked to set everything up by hand (e.g. fieldsize, gantry, collimator)







The Virtual Linac – Practical work

- Groups of 6-9 split into two
  - One group would perform the 'set-up'; one the calculations
  - All had individual workbooks with experimental methods and calculation forms
  - VERT setup done by hand, so that get used to hand controllers
  - All done from scratch – like a definitive calibration
    - Block would need to be set up
      - Correct SSD
      - Correct Gantry, collimator, floor angles and field sizes
      - Correct depth in the block
  - Workbooks completed and forms recreated on whiteboards for students to complete
  - Calculations done by the calculation group – but all had chance to
    - Try these at the end
    - Be tutored as a group and individually as they ask questions
    - Have guidance and try different calculation methods
    - Complete the worksheets
- Swap over for the next 'experiment'
- Evaluation sheets (anonymous) completed at the end

E.g. Experiment 1 (of 3)

RADT703 2015 VERT PHYSICS Sessions 11th May 2015

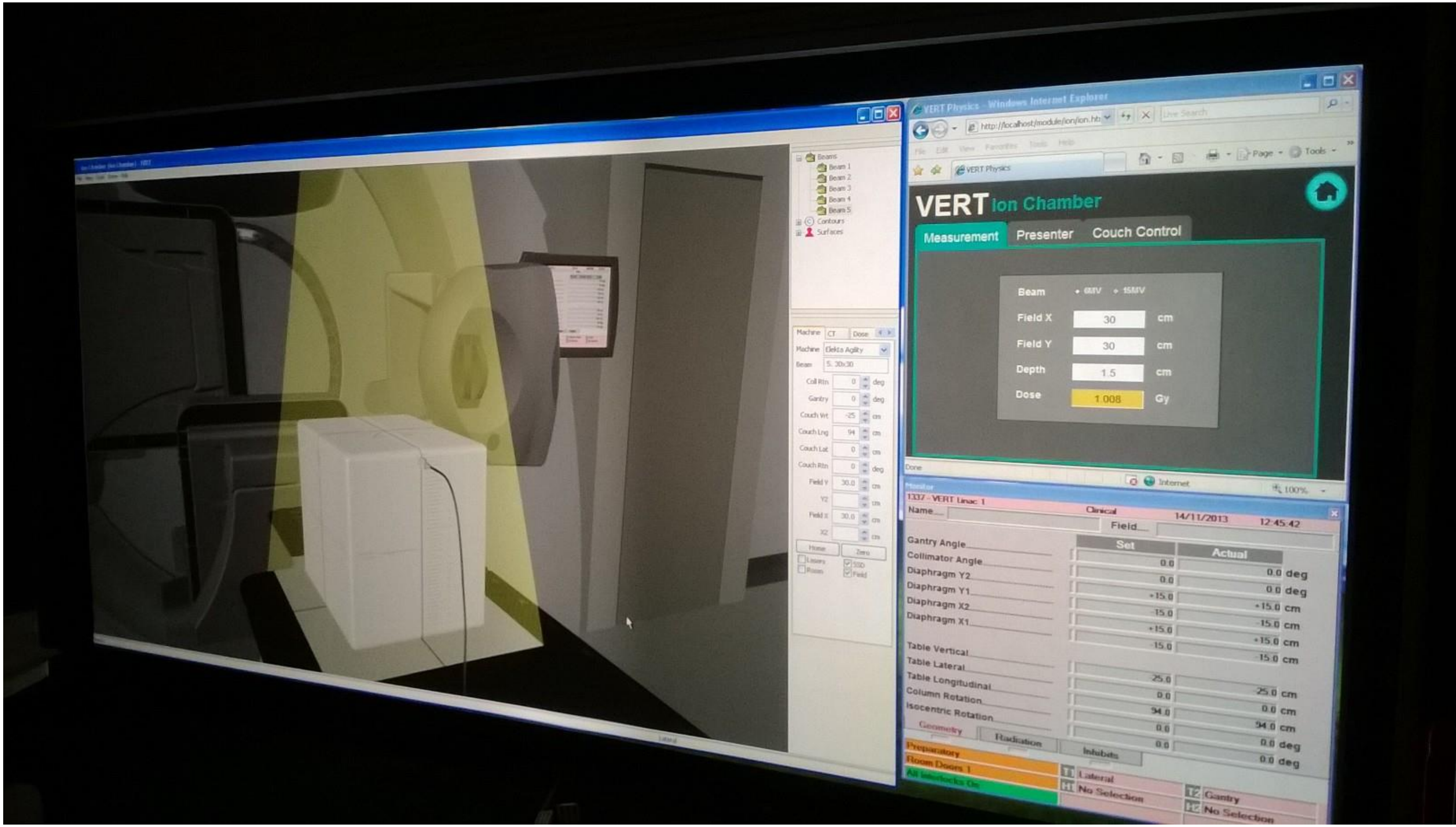
Experiment 1 – Inverse Square Law and delivered dose

Planned Prescription – 100 cm SSD, 15 x 15 fieldsize (jaws), Gantry angle 0, Collimator angle 0, prescription point is 5 cm deep; 8Gy single fraction treatment

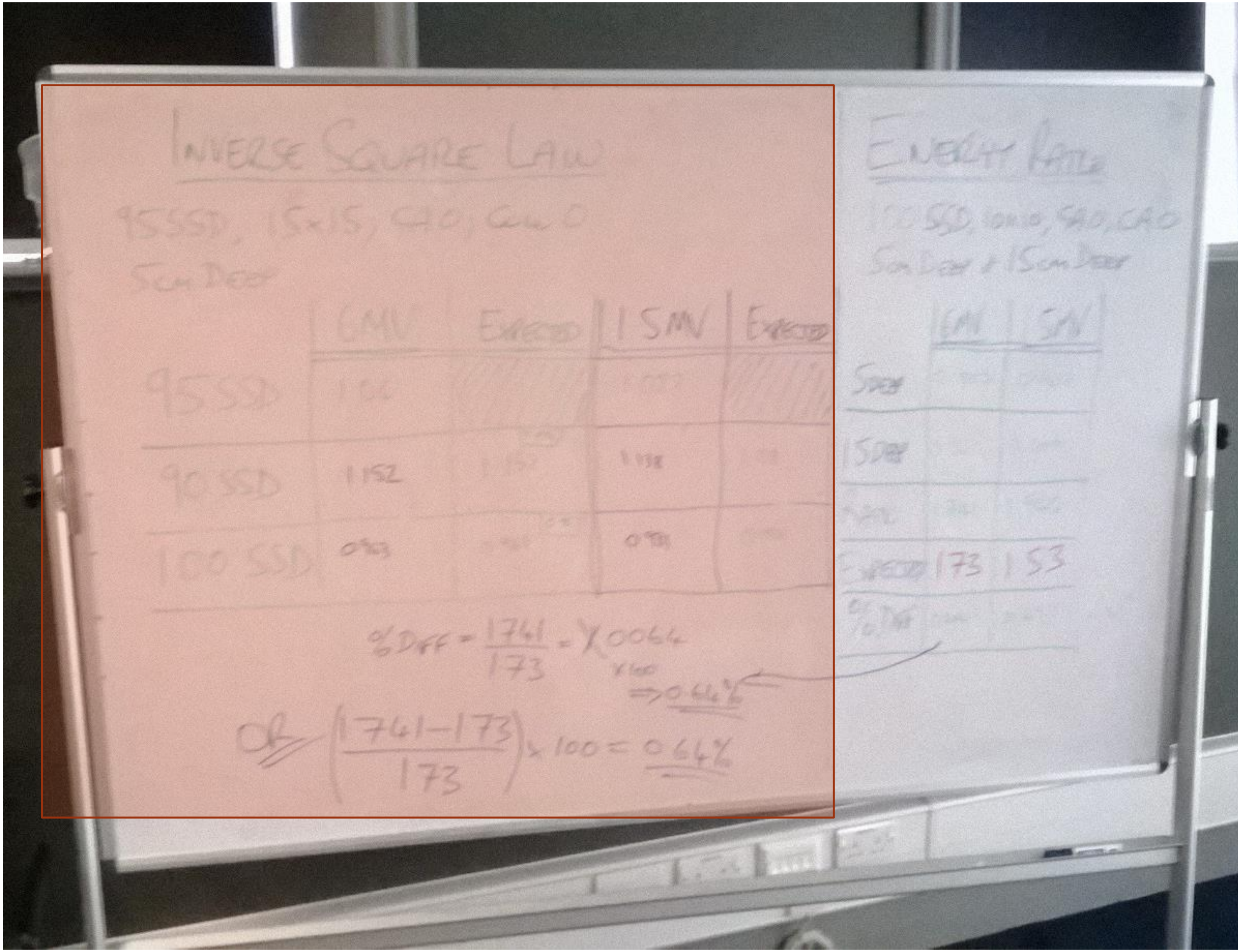
Complete the table below, working as two groups – one to set up the phantom on the couch as the patient; one group to perform the mathematics; swap over for the different energy

	6 MV			15 MV		
SSD	ISL Factor	100 MU measured dose (Gy)	100 MU expected dose (Gy)	ISL Factor	100 MU measured dose (Gy)	100 MU expected dose (Gy)
100						
95						
105						

WORKSPACE



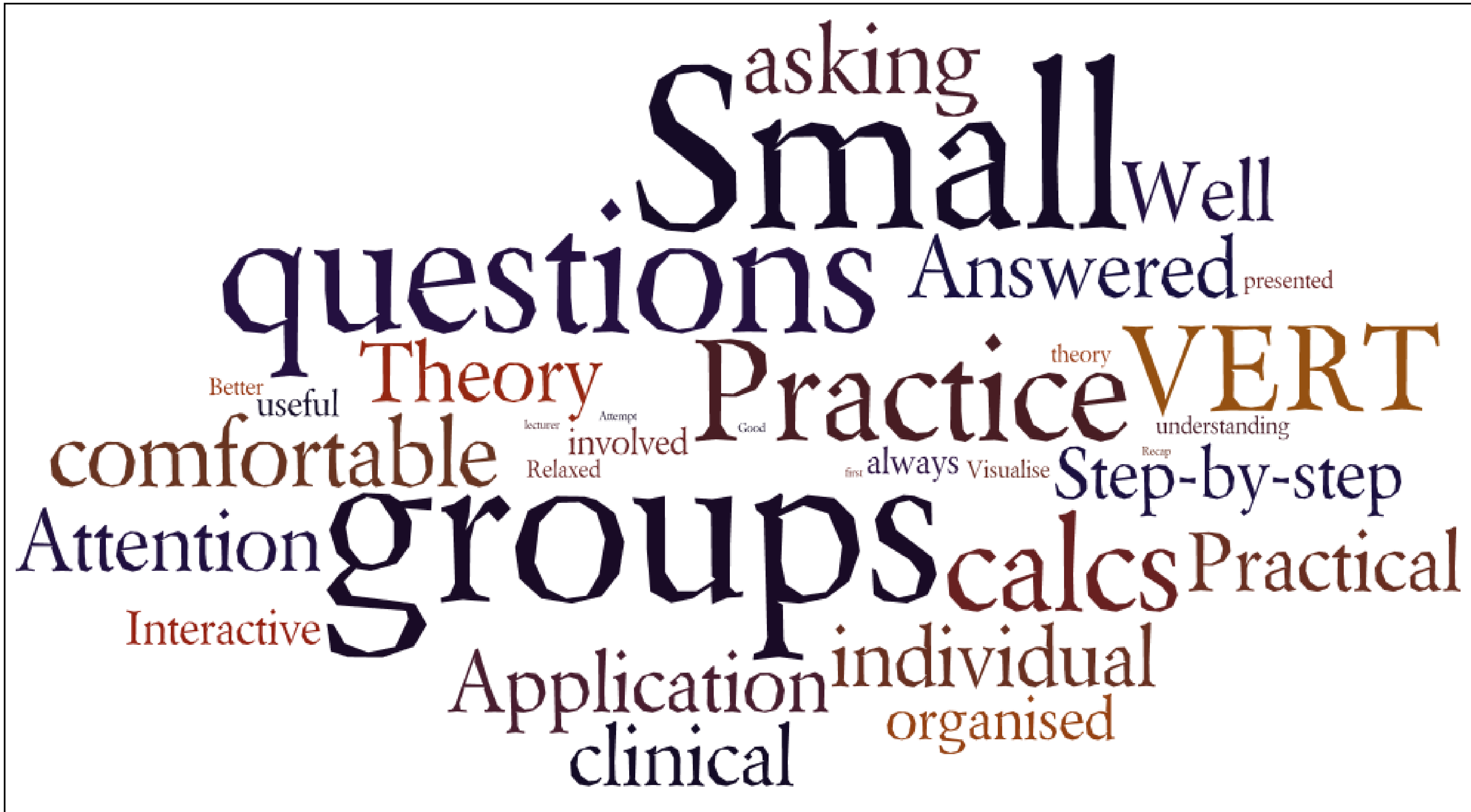
UNIVERSITY OF LIVERPOOL

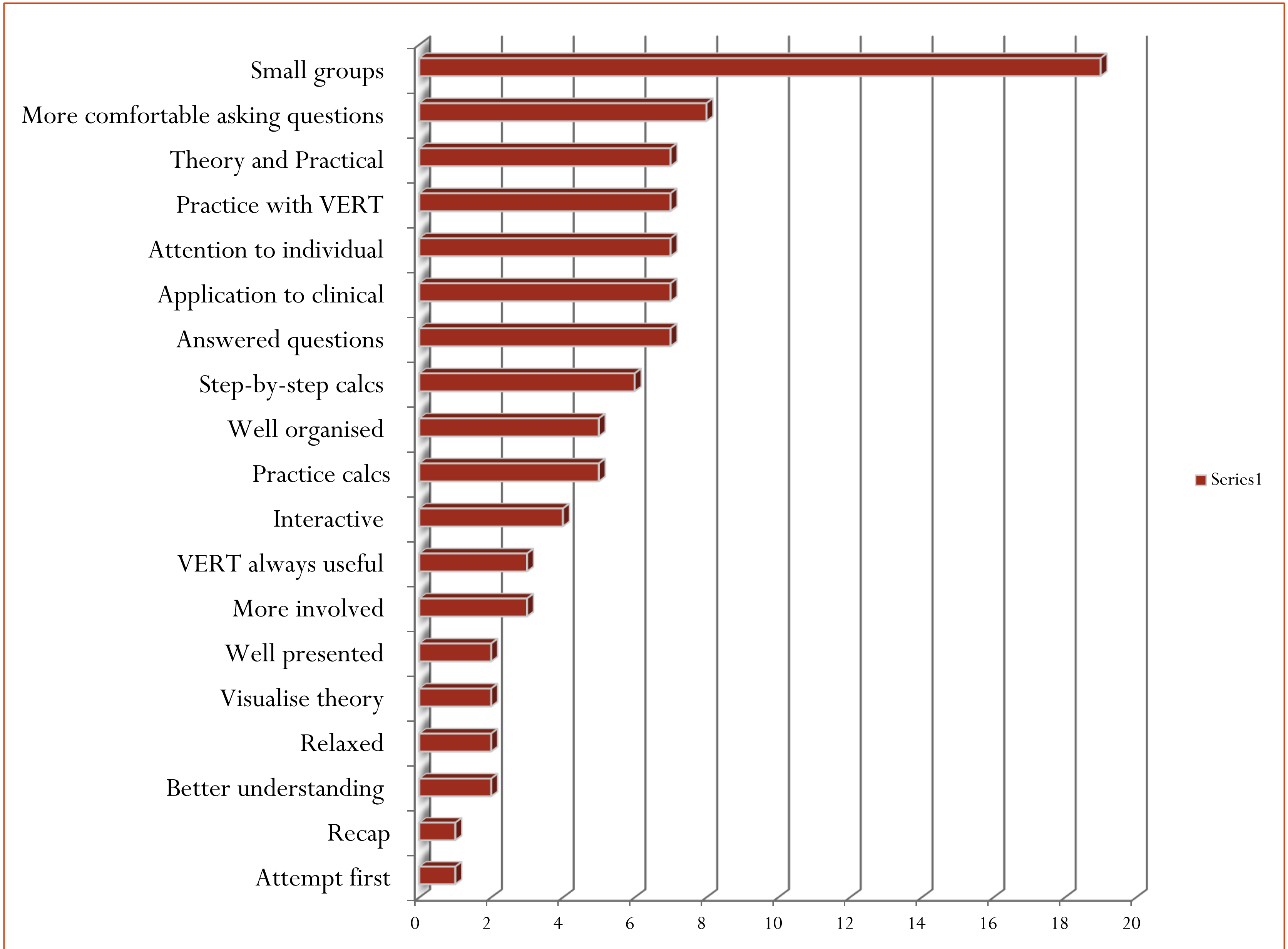

INVERSE SQUARE LAW
ENERGY RATIO
6MV
EXPECTED
15MV
EXPECTED
95SSD
90SSD
100SSD
6MV
15MV
EXPECTED 1.73 1.53
%DIFF = 1.741 / 1.73 = 1.0064
⇒ 0.64%
OR (1.741 − 1.73) / 1.73 x 100 = 0.64%

Results (2014-2016)

- VERT Physics practicals – software easy to use; made the lectures 'come alive' and illustrate the application
- Students would 'take measurements' on their own on virtual linac using VERT Physics software – as we would do in the clinic
- Illustrate important clinical concepts (e.g. dosimetric effect of wrong SSD); assess the clinical magnitude; judge whether the error is reportable for single/multiple fractions
- Students liked interactive nature – working on the Virtual treatment machine; performing experiments as if in the clinic; working in small groups to work out the 'math' and confirm predictions with the measurements; expert tutoring in small groups

Student responses - evaluations




Small groups
More comfortable asking questions
Theory and Practical
Practice with VERT
Attention to individual
Application to clinical
Answered questions
Step-by-step calcs
Well organised
Practice calcs
Interactive
VERT always useful
More involved
Well presented
Visualise theory
Relaxed
Better understanding
Recap
Attempt first
0
2
4
6
8
10
12
14
16
18
20
Series1

Published Results – 2015

TEACHING RADIOTHERAPY PHYSICS CONCEPTS USING SIMULATION: EXPERIENCE WITH STUDENT RADIOGRAPHERS IN LIVERPOOL, UK

M C Kirby, PhD

Directorate of Medical Imaging and Radiotherapy, School of Health Sciences, University of Liverpool, Liverpool, UK

Abstract— Therapeutic radiography students (student radiation therapists) are challenged with acquiring a wide range of clinical, empathetic and technical skills for the benefit of cancer patients. Certain aspects of the technical skills (radiotherapy physics) can be difficult since they are not practical experiences encountered by the students' first-hand in their clinical placements. As part of a wide ranging, blended learning approach, real-world technology is used in our directorate together with hybrid virtual radiotherapy systems (VERT™) to enhance student learning and provide an engaging, safe and effective environment for it. This paper discusses our experiences with the physics module of VERT™ with year groups disseminated into small groups to undertake practical experiments using the VERT™ system in the same way one would use a real clinical linear accelerator for teaching with dosimetric equipment. Key concepts such as inverse square law and dosimetric consequences of incorrect set-up (SSD), measurements of quality control parameters and derivation of key data charts were the three main experiments examined here. Undergraduate and postgraduate radiotherapy students were divided into workgroups with specially designed training and workbooks for performing calculations and verifying predictions with simulated dosimetric measurements. Our results, from evaluations performed by all students, coded and analysed into common themes of response, showed that students engaged extremely well with the process, finding these methods valuable, practical and engaging particularly in terms of linking theory and practice and enhancing their skills. Minimal less positive responses were received and the majority appreciated the individualized tutoring which was the natural result of small groups engaged with the virtual software and this highly kinesthetic environment. We found that VERT™ Physics and this practical method of simulated dosimetric measurements is a highly productive learning environment; helping students apply theory to clinical situations and learn in a more illustrative and dynamic way.

Keywords— Simulation, radiotherapy physics, radiographers, virtual environment, VR.

I. Introduction

The teaching of modern, 21st century radiotherapy to therapeutic radiography students (student radiation therapists) is challenging, requiring the development of in-depth clinical and empathetic skills with appropriate patient care and compassion, with sufficient understanding of complex radiation physics and technology. The latter is understandably difficult, since elements of (for example) beam data generation, quality control measures and radiation dosimetry are not experiences encountered first-hand in clinical placements.

It is found that for the allied health workforce, a blended learning approach is often viewed as best practice for developing these complex qualitative and quantitative skills – by carefully integrating online and web-based learning methods with more traditional face-to-face experiences [1]. The approach also ensures that the teaching is both research-led and research-informed - two of the key research typologies proposed by Griffiths (p11 of [2]), producing an environment which is research based and highly valued by students in their learning experience [3].

Within the University of Liverpool, our aims and objectives have always been to do this and take the blended approach a step further; expanding the range of experiences and learning strategies, and developing skills (complementary with clinical competencies) using real-world radiotherapy technology. This is naturally achieved in the clinical placement setting, but can also be complemented by a range of real-world radiotherapy technologies and software in the academic setting – lending itself to a safe but clinically effective environment [4, 5].

The use of the Virtual Environment for Radiotherapy Training (VERT™) (www.vertual.co.uk) has been a key component in this approach in our university and across the UK for many years [6-8], providing a hybrid virtual environment skills facility, initially simulating radiotherapy equipment and treatment rooms, and then developing to visualize anatomy and planned dose distributions for both simple and more complex radiotherapy techniques (from, for example, simple single fields to complex IMRT and VMAT). Following a potential crisis in England for training staff and students for radiotherapy treatment of cancer, in 2007/8 the UK government provided VERT™ to all clinical radiotherapy departments and those universities involved with radiotherapy education. Since that time, the use of VERT™ has developed internationally for the highly successful training of student and qualified radiographers (radiation therapists) [9-12] through its various hardware and software platforms (www.vertual.co.uk) – from full 3D immersive laboratory facilities (a 'hands on' mode with real radiotherapy equipment hand pendants) to desktop/laptop/tablet versions for demonstrating radiotherapy planning, anatomy and delivery to staff and patients alike using workbooks and other methods. The software is not open source or freely available; it is a commercial product, but its various software versions enable it to be used in more modest economies (e.g. with a

MEDICAL PHYSICS INTERNATIONAL Journal, vol.3, No.2, 2015

laptop and extended desktop to a large monitor) very effectively

Recent developments in the software have introduced components which help students with some of the fundamental concepts and practicalities of radiotherapy physics [13-15], with the advantages again of helping students learn these challenging topics (which are more remote from their clinical day-to-day experiences) in a safe and accessible environment. Our experience with using the software for teaching student radiographers at both undergraduate and postgraduate level in this highly kinesthetic manner is the focus of this paper; where the VERT™ Physics package is used to demonstrate not only commonly used dosimetric equipment and it use, but also to simulate a medical linear accelerator (linac) for performing virtual dosimetric experiments. The work reported here has been run with second year undergraduates and both first and second year postgraduate radiotherapy students for the last two academic years – approximately 40 in total for each year.

II. Materials and methods

A. Methods

A.1 Groups and revision lecture: Each year group was divided into smaller groups, with a maximum of 7 students in each. This was done to ensure that the 'hands-on', kinesthetic nature of the practical work could be undertaken by all students. For the first year of working with the software, a formal lecture was held immediately prior to the practical work to help students revise and recall the foundational scientific concepts for the 'virtual' experiments which would be performed (Fig 1). This recap focused on;

(i) the concept of inverse square law and the dosimetric effects to the patient of setting incorrect SSDs

(ii) the collection of central axis percentage depth dose data (using a water tank) and the measurement of quality indices in routine quality control checks and

(iii) the collection of data and the derivation of field size factors for manual monitor unit calculations.

This lecture was not undertaken in the second year, in order to allow more time for practical experiments – in direct response to the student evaluations.

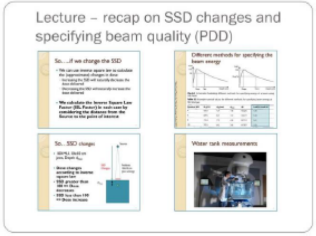


Fig. 1 Example of the presentation slides given during the revision lecture before the practical experiments using VERT™

A.2 VERT™ Physics overview: At the start of the practical experiments, a demonstration overview of the VERT™ Physics software was given by the tutor, followed by detailed instructions on how the students would use the software in conjunction with the virtual linac. Aspects of the demonstration are shown in Figure 2.

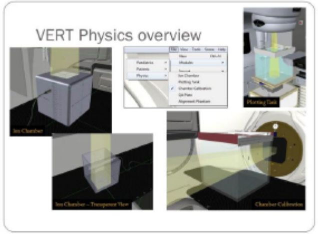


Fig. 2 The demonstration overview given to students of the VERT™ Physics software, prior to practical experiments

The demonstration included dosimetric methods using a Farmer type ionization chamber within a tissue equivalent solid water phantom; typical data collection using a water tank (central axis depth dose curves and beam profiles); and the principles of cross-comparison for ionization chamber calibration. Being a virtual system, the concepts of isocentricity and alignment were also demonstrated using modes whereby the solid water phantom could be rendered translucent.

Evolution.....

- First iteration (2014)
  - Lecture followed by practical work
- Second iteration (2015 and 2016)
  - Practical work only
- Third iteration (2017 and 2018)
  - Interactive Demonstration plus some practical work

Why change??

- First iteration (2014)
  - Lecture followed by practical work
- Second iteration (2015 and 2016)
  - Practical work only
    - In response to student feedback – wanted to get to the practical work straight away
- Third iteration (2017 and 2018)
  - Interactive Demonstration plus some practical work
    - **In response to module evaluations (more VERT)….and exam results (could be better!)**

Certain fundamental Physics concepts.....

- Could be (needed to be, for clinical practice) better understood
- Look for ways to use VERT to teach, <u>in addition</u> to lectures
  - Since VERT was naturally more interactive
  - ….and the students were hungry for more teaching with it

- Current iteration (2017 and 2018)
  - Interactive Demonstration plus some practical work

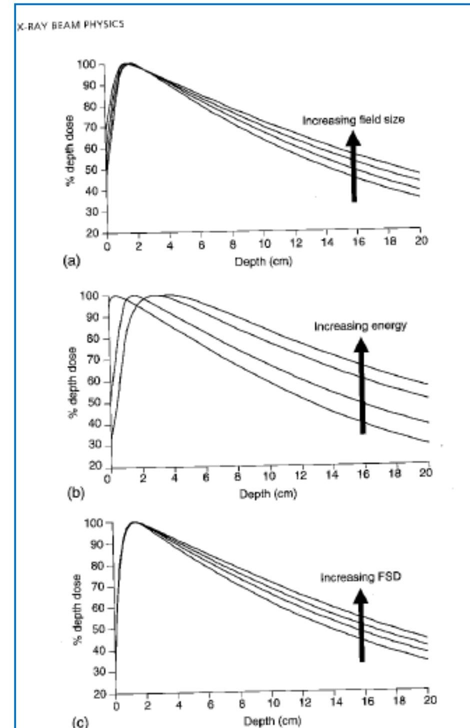
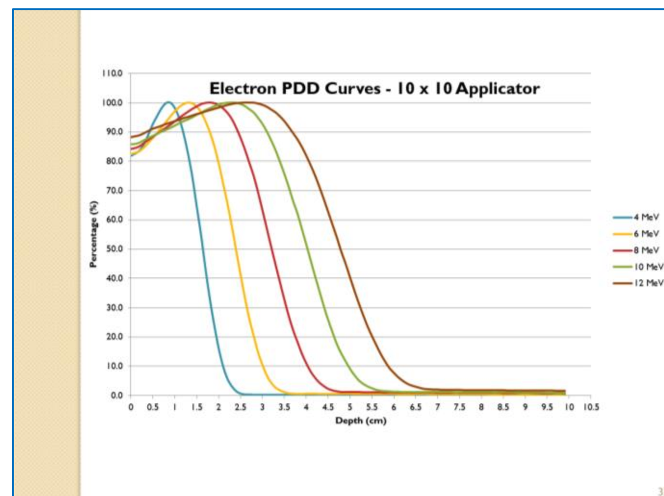


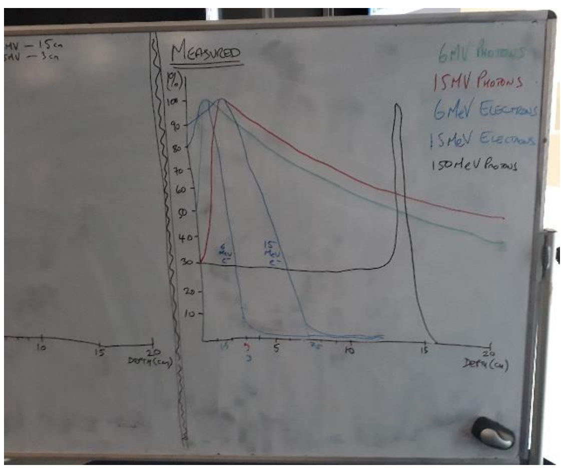
Fig. 8.5 Variation of % depth dose with a) field size for square fields of sides 5, 10, 20, 40cm at 6MV; b) with energy for Co-60, 6MV, 15MV and 25MV; c) with FSD for 80cm,

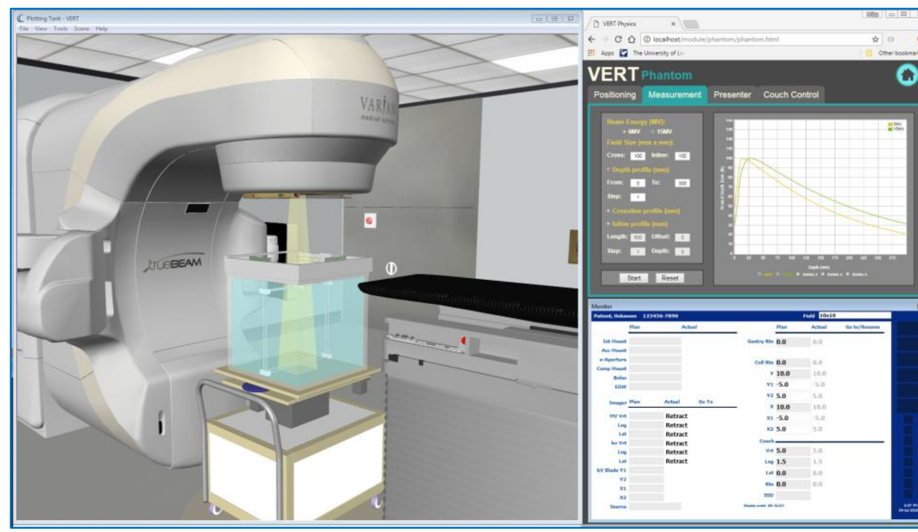
Taken from ‘Physics for Clinical Oncology’, Oxford, 2012



Third iteration (2017 and 2018)…..

- Interactive Demonstration (come and see it tomorrow!!)
  - Workbooks extended – tutor discussion and demonstration of concept and why clinically important
    - Students attempt 'prediction'; safe, formative, individual guidance and feedback
    - Predict in own workbooks and on white board
    - Confirm with demonstration in VERT Physics virtual environment
    - Final versions drawn on whiteboard





- plus some practical work, as before

E.g. Interactive Demo – changes with photon energy

School of Health Sciences

Directorate of Radiotherapy

RADT722 201718

Science for Radiotherapy 2

RADT722 201718 VERT PHYSICS Session

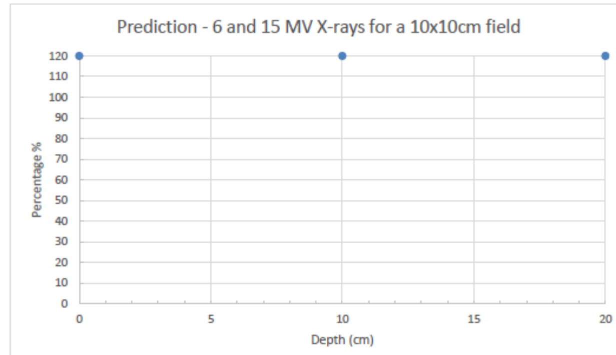
26th March 2018

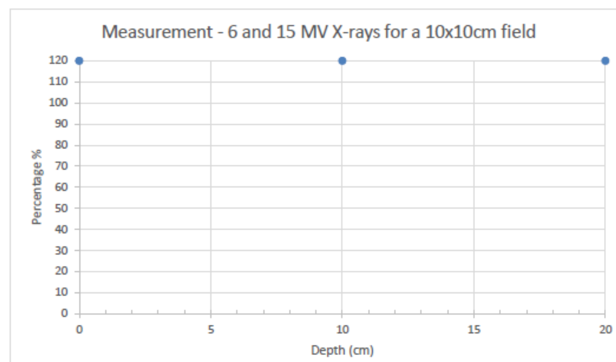
RADT722 201718 VERT PHYSICS Sessions 260318.docx Page 1 of 7

I - Prediction and Demonstration of Percentage Depth Dose Curves

The central axis percentage depth dose (PDD) curve is one of the most fundamental aspects of photon treatment fields and dose deposition in external beam radiotherapy. The plotting tank (as demonstrated by the lecturer using VERT Physics) is the primary way that we measure such curves in commissioning a linear accelerator. Dividing the group into two teams, one team use VERT Physics to measure percentage depth dose curves, whilst the other team predicts what the curves should look like.

DIFFERENT ENERGIES – Predict and measure the PDD Curves for 6 & 15 MV X-rays, for a 10x10 cm field





RADT722 201718 VERT PHYSICS Sessions 260318.docx Page 2 of 7

UNIVERSITY OF LIVERPOOL

Results – from anonymised evaluations

- Good Points
  - Very useful! Really helps us understand…..need more sessions like this
  - Very interactive. Liked being given chance to predict before answers
  - Good to work in group/more interactive session; enjoyed using VERT, easier to understand/visualise
  - Good mix; good groups sizes for practical
  - Useful to see it on VERT rather than just explained in theory
  - Very well taught; very helpful in explaining important principles
  - Very informative, well explained; nice to use VERT; good workbook
  - Helpful to understand clinical relevance of theory; small groups – easier digestion of material
  - Very good and clear explanations; understood more afterwards
  - Really useful, well explained – nice to use this valuable resource. Fantastic!

- Not so good points
  - Need more time (for the practical problems); longer session; a little rushed (practical)
  - More opportunity for both groups (for the practical problems)
  - More time……

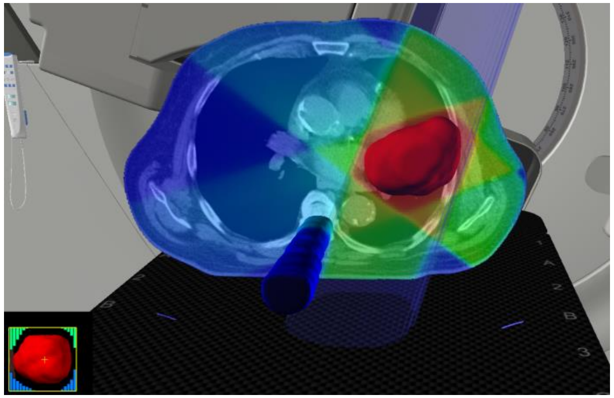
- Next time, why not try
  - Longer sessions; more sessions like this; longer sessions…..
  - Lots did not comment here!

Conclusions

- The VERT Physics virtual environment continues to work extremely well as a teaching tool
- Students find it very useful, helpful, interactive; easier to understand concepts
- Enjoy working in small groups, and keen on doing calculations and 'operating' VERT
- Timing and longer sessions was most negative point – all focused on the practical aspect (which was always conducted after the interactive demo)
- Safe, relaxed environment – does not take up valuable time on a real treatment machine
- Can 'see' things not possible in the real world; helps understanding
- Currently doing full analysis of evaluations; and exam questions over the last few years – improvement in understanding?

Futures

- Model for future small group work, no matter what the professional discipline
  - Based around real clinical/physics practice; can simulate the linac at all hours – availability!
- Follow feedback – and extend the sessions/more sessions; use for teaching more Physics
- Use same structure – small groups; expert and peer-to-peer teaching; interaction – workbooks and whiteboards; practical experiments
- For more advanced classes….
  - Students given clinical problem
  - Formulate experiment themselves
  - One group does theoretical solution and predicts result
  - One group does practical measurement and confirms result
  - Compare and reflect
  - Matches clinical development



Thank you for your attention!

- Contact:
  - mckirby@liverpool.ac.uk

Gracias

Obrigado!

Merci

Thank You

Grazie

Ευχαριστώ

UNIVERSITY OF LIVERPOOL